Chapter 3. Thermal Expansion

Presentation by

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Objectives

- Define thermal expansion

- Identify the factors affecting thermal expansion

- Solve sample problems involving linear expansion and volume expansion

- Cite everyday applications of the concepts

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Thermal Expansion

- Change in the dimension(L) of a substance due to change in temperature

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Factors Affecting

THERMAL EXPANSION

- The original length L_o

- The temperature change ΔT

- The kind of material

1- Temperature

- Higher change in temperature, the higher the expansion.

- ΔT **for the symbol**

2- Thermal Expansion

Change in the dimension(L) of a substance due to change in temperature

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3- Kind of Material

- Quantified by a constant value for **coefficient of thermal expansion** for some materials

- The higher the coefficient, the higher the expansion

- Symbol used - α

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Original Dimension

- **Greater original dimension, greater the expansion.**

☐ *L* **for linear expansion**

☐ *A* **for area expansion**

☐ *V* **for volume expansion**

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$$\Delta L = \alpha \cdot L_0 \cdot \Delta T$$

Change in dimension

Coefficient of expansion

Original length
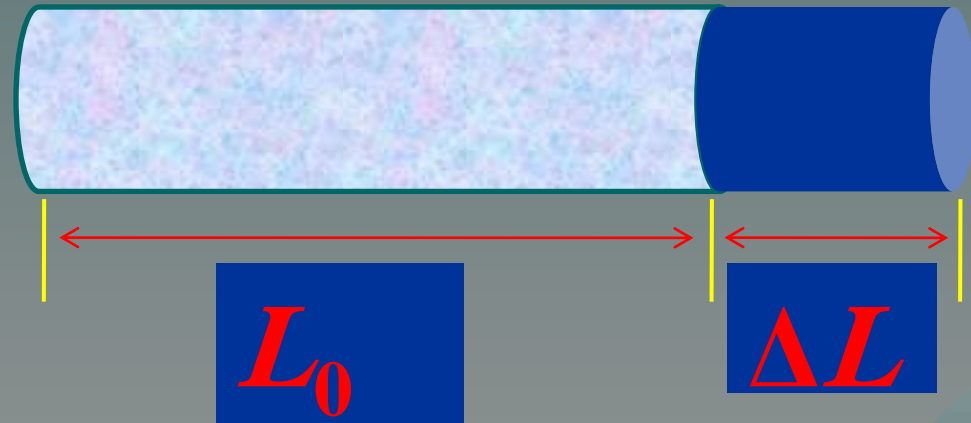
Change in temperature

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Types of Expantion

1-Linear Expansion

· **Suppose a rod of material has a length L_o at some initial temperature T_o when the temperature changes by ΔT, the length changes by ΔL.**

$$\Delta L = \alpha \cdot L_0 \cdot \Delta T$$

$$L_0$$

$$\Delta L$$

So, the length L at a temperature $(T = T_o + \Delta T)$ is:

$$L = L_o + \Delta L = L_o + \alpha L_o \Delta T = L_o (1 + \alpha \Delta T)$$

The fractional length change $= \Delta L / L_o$

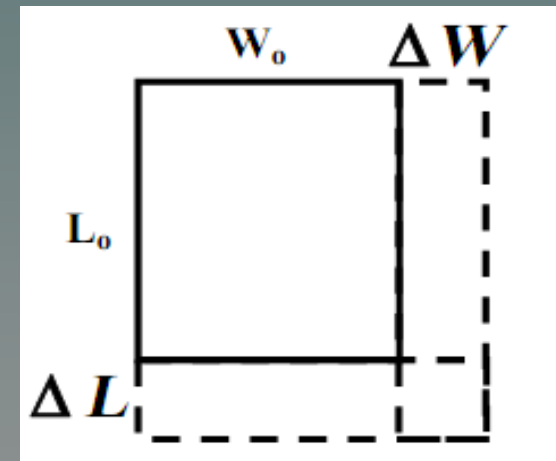Prof. Dr. Moustafa TAwfik Ali Ahmed

2-Area Expansion

-*Suppose a rectangular face of a block has a length of L_o and width of W_o at some initial temperature T_o.

-*If the material has a linear expansion coefficient α and the temperature is changed by ΔT then:

-The new length is $L = L_o (1 + \alpha \, \Delta T)$

The new width is $W = W_o (1 + \alpha \, \Delta T)$

The original area is $A_o = L_o \, W_o$

The new area is $A = L \, W = L_o (1 + \alpha \, \Delta T) * W_o (1 + \alpha \, \Delta T)$

$A = L_o \, W_o (1 + \alpha \, \Delta T)^2 \approx L_o \, W_o (1 + 2\alpha \, \Delta T) \approx A_o (1 + 2\alpha \, \Delta T)$
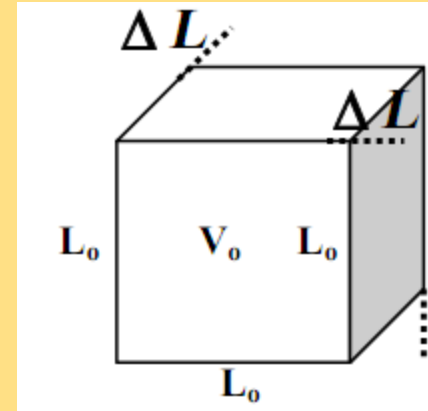
$A \approx A_o (1 + \beta \, \Delta T)$ where $\Delta A = A_o \, \beta \, \Delta T,$ $\beta = 2 \, \alpha$

if the temperature of a disk with a hole has changed (increase or decrease) then the dimension of the disk and the hole is changed (increase or decrease).

3- Volume Expansion

Temperature increases usually cause increases in volume for both solid and liquid materials.

*The increase in volume ΔV is proportional

to the temperature change and the initial

volume V_o

$$V = L^3 = [L_o (1 +\alpha \Delta T)]^3 = L_o^3 (1 +\alpha \Delta T)^3 = V_o [1 +(\alpha \Delta T)]^3$$

$$= V_o [1 +3 (\alpha \Delta T) + 3 (\alpha \Delta T)^2 + (\alpha \Delta T)^3] = V_o [1 +3 \alpha \Delta T]$$

$$V \approx V_o (1 + \gamma \Delta T) \quad \text{where} \quad \Delta V = V_o \gamma \Delta T \qquad \gamma = 3\alpha$$

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Thermal Expansion

- **Linear Expansion**

$$\Delta L = \alpha L_0\, \Delta T$$

- **Area Expansion**

$$\Delta A = 2\alpha A_o\, \Delta T$$

- **Volume Expansion**

$$\Delta V = \beta V_o\, \Delta T$$

$$\Delta V = 3\alpha V_o\, \Delta T$$

- The original volume of a liquid is V_o at T_o .

- *The real increase in volume of the liquid at T is :

- $$\Delta V_L = \gamma_L \, V_o \, \Delta T$$

- * The real increase in volume of the container at T is :

- $$\Delta V_S = \gamma_s \, V_o \, \Delta T$$

- *The apparent increase in volume of the liquid =

-     Real increase in volume of liquid - Real increase in volume of container

- *The apparent increase in volume of the liquid $= \gamma_R \, V_o \, \Delta T - \gamma \, V_o \, \Delta T$

- $\Delta V_a = \Delta V_L - \Delta V_S = V_o \, (\gamma_L - \gamma_s) \, \Delta T$

- $\Delta V_a = V_o \, \gamma_a \, \Delta T = V_o \, (\gamma_L - \gamma_s) \, \Delta T$

- * $\gamma_a \equiv (\gamma_R - \gamma)$